

## **“Non thermal effects and mechanisms of interaction between EMF and living matter: a selected Summary”.**

ICEMS, eds. L. Guiliani & Soffritti M : Ramazzini Insitute, European J of Oncology, Library, Vol 5, 2010. Summary :David Gee, Feb 18 2011

This Monograph by the International Commission for Electromagnetic Safety (ICEMS) edited by Guiliani, from the Italian National Institute for Prevention & Safety at Work, and Soffriti, director of the Ceasare Maltoni Cancer Research Centre, Ramazzini Institute, Italy, includes 25 scientific papers in 400 pages and summarises the non thermal biological effects of EMF. (Page refs are to those in the monograph).

**Non thermal** effects defined therein are biological mechanisms that are not able to induce a temperature increase higher than 0.01degrees C (living organism) ,0.001(cells) ,or 0.0005 (sub-cellular).

By comparison, ANSI, WHO, IEEE & ICNIRP consider that exposures below 0.05 degrees C (0.4W/kg) are safe for workers, and exposures below 0.01 C (0.08 W/kg) are negligible for the public.\_

Any biogical effects below these levels are considered by these organisations to have no biological significance and to be reversible. (px1)

There is some dispute about the concept of non-thermal effects that, inter alia, involves debates about the focus and nature of the temperature being debated. Guiliani maintains that as the scientific focus shifts from the independent particles of *atomic physics* to the dependent molecules and greater complexity of *biophysics* there is a need to see temperature as a feature of the *system*, not of its components. (p1x)

There a few key issues at the heart of the EMF, (both ELF from power lines etc ,and the RF from mobile phones etc) controversy.

This selected Summary is constructed aroundsome of these main issues.

### **1. Biological Plausibility and Scientific Paradigms**

**The current conventional paradigm** used by the main authorities on EMF (eg IEEE, ICNIRP, WHO, the EU Commission) is based essentially on the thermal effects of EMF. This in turn is based on classical engineering assumptions and theories arising originally from Faraday

which assume that energy transfer in biological matter is based on “hopping” along discrete energy levels.

However, this paradigm cannot explain observations such as, for example, “photosynthesis, where light absorbing molecules can funnel energy with a near unit quantum efficiency across mesoscopic distances” (Guiliani, L. p x, ).

When observations can no longer be explained by existing paradigms, some scientists begin to question the conventional theories and begin the search for new explanations and theories which can better explain the new observations.

(See the story of cholera in the London of 1854, which involved new observations about cholera being caused by water pollution rather than by air pollution, which was the dominant paradigm of the day. “Late Lessons from Early Warnings” Introduction).

When there are no shared biological explanations and understanding about why some experimental observations happen, “the scientist faced with choosing between well replicated observations and contrary calculations based on existing theory must always opt for the former” . (Liboff, p66).

(This is analogous to the position of Galileo 400 hundred years ago when he published “The Starry Messenger” which contradicted the conventional paradigm that the Earth was stationary and the sun moved round it. His subsequent lifelong house arrest by the Vatican was an extreme example of “shooting the messenger”. This has its current counterpart in personal attacks on some scientists who promote the non thermal , low level effects of EMF).

The conventional paradigm is, as is nearly always the case in science, defended vociferously. For example:

Professor Ahlbom (Karolinska Institute), said, in 2001, that the asserted association between mobile phones and brain tumours is “biologically bizarre”. ( Adami H.O., Ahlbom A., Ekbom A., et al, “Opinion: experts who talk rubbish”, Bioelectromagnetics Society Newsletter, 2001, 162:4-5).

There are several **emerging competing paradigms** for the non thermal biological behaviour of EMF. They are based essentially on Quantum Electro-dynamics and informational physics. These more modern theories are needed to help explain the observations, first made separately by

Liboff and Blackman in 1985, that alternating and static magnetic fields can resonate with the cyclotron frequency of some metallic ions in biological tissue eg calcium, potassium, magnesium.

Zhadin, in the 90s, then found that these resonant effects of AC magnetic fields also occurred with solutions of alpha amino acids at exposure levels that were 1000 times lower than even the very low levels used by Liboff and Blackman ie around 40 nano tesla.

(The Bioelectromagnetics journal would not publish these remarkable results from Zhadin until some biologically plausible mechanism was proffered by him, which came 4 years later, in 1998. p 2).

His results have since been independently replicated in 3 other laboratories.

The results are consistent with the DC magnetic field sensitivities of birds, bees, bacteria, lobsters, sharks, termites ,bats etc., which can be around levels of 10-100 nanoTesla. (Liboff , p51)

The possible biological explanation for Zhadin's results was based on the idea that water (which makes up about 70% of the mass, and 99% of the molecules, of living matter) has two components, one "coherent", the other "incoherent", (with respect to molecular movements), and these differ both from each other, and from water as a whole, in terms of, for example, their viscosity and oscillation damping.

Living organisms are complex systems in which millions of molecular components interact with large amounts of water and display configurations that are quite different from the one assumed when they are isolated ie the systems have "emergent properties" that arise only at the level of the system and which cannot be predicted from the individual parts.

Understanding the role of biomolecules in biological systems can only begin when the two main matrices that determine their functions, water and electromagnetic fields, are taken fully into account, as Albert Szent-Gyorgyi pointed out in 1957.

"Given the basically electromagnetic character of this organisation it is not surprising that living organisms are able to interact with external electromagnetic fields in a non thermal way". (Del Guidice E. Guiliani L, p 14) .

“Water performs important functions in determining the shape and function of proteins... (providing) flexibility to the proteins ..(and ) catalysing the chemical reactions with oxygen that produce the energy for living matter”. (Tigrek S , Barnes , F. “”Water structures and effects of electric and magnetic fields”, p 25-50).

## **2. Low dose effects and “windows of sensitivity”**

Such non thermal effects do not produce the classical linear dose response effects that the Bradford Hill “criteria” of 1965 regarded as one of 9 features of evidence that could help move from an observed association to an inferred causal relationship.(**Table 1**).

Instead, the experimental evidence on EMF shows a “window” of responses to magnetic intensities which are absent at higher and lower intensities.

The “window of sensitivity “ in the EMF field is similar to the “low dose” effects of some endocrine disrupting and other chemicals, such as BPA, where low exposures have biological effects that are absent from higher doses.

There is also a large and growing body of evidence that demonstrates the extra sensitivity of the developing foetus to environmental stressors. This can help explain the developmental origin of many diseases, such as cancer and diabetes, which appeared to be caused by lower levels of exposure than previously thought. (PPTOX 1 papers in Basic and Clinical Physiology & Toxicology, Mar 2007 ??; **PPTOX 2 papers, NIEHS, XXXXXX J 2010??**).

These “windows of sensitivity“ to EMF are also often dependent on the time, and therefore stage of development, of the biological matter being irradiated.

That “the timing of the dose” is at times more important than the dose itself is a well known scientific phenomena that was learnt the hard way via the histories of some medicines.

For example, Thalidomide, where gross deformities in the new born came only when the pill by the pregnant mother was taken between day x and M (Gee, 2009) ; and another pregnancy pill ,DES ,which later caused vaginal cancer in the adult daughters. (See chapter on DES in “Late Lessons from Early Warnings: the Precautionary Principle 1896-2000”, EEA, 2001).

Thus it is the timing of the dose of an environmental stressor that can be critical for its biological effects, rather than just the amount of the dose.

It follows from this that prevention of such diseases must begin at earlier times in the exposure of the foetus, and justified by lower strengths of evidence, if lifelong harm is to be prevented. ( *Gee 2009.ref?*)

The field intensities detectable by animals are very low: the racing pigeon can detect changes as little as 100-1000 times lower than predicted from engineering calculations; and honey bees are estimated to be 10 times more sensitive to magnetic fields than the pigeon. The scalloped hammerhead shark meanwhile can detect changes in electric fields as low as 0.5 microvolts /m. (p 53/4).

If this “window” of sensitivity is not taken into account when interpreting epidemiological results then important biological effects can be dismissed.

For example, the significant association of acute lymphoblastic leukemia in children exposed to ELF from powerlines with magnetic field strengths of 0.4-0.499 microtesla was not observed at either lower or higher field intensities in the 1997 Linet study. This was interpreted by Linet as showing “little evidence” of an effect because of the absence of effects in the other 6 categories of field intensity. (Liboff , p 52).

Other studies since confirmed this association of children living near power lines and leukemia, first observed in 1979. Such exposures were classified by the IARC as a “possible (“B) carcinogen in 2002.

### **3. Biological Plausibility?**

A second Bradford Hill “criterion” is biological plausibility ie does the observational evidence compatible with the known science?. This is dependent on current knowledge, which is always vulnerable to advances in science, and is therefore not a very robust basis for dismissing new evidence.

(If new evidence is compatible with known science then it is likely to provide a more robust basis for accepting the evidence: this illustrates the asymmetrical nature of the Bradford Hill “criteria” ie if present from high quality studies they can be a robust basis for accepting an observed association as real, but if absent they cannot necessarily be a robust basis for dismissing the association).

The scientific literature does now have several strong candidates for the biological explanation for non thermal effects, such as the combined free radical pair/oxidative stress mechanism. (Giorgiou, C.D. , p 64, and 103 for a diagram illustrating this ).

Oxidative stress is implicated in cancer and neurodegenerative diseases such as Parkinson's and Alzheimer's.

There are also several other possible biological explanations for low dose non thermal effects of EMF such as chemical kinetic effects ;stochastic resonance; electrically induced phase transitions; cyclotron resonance; resonant transport of ions; coherence effects; signal averaging rectification; parametric resonance; ion interference; coherent excitations; alterations of metastable water states; effects of torsion fields: and combinations of the above. (158).

The biological reality of the non thermal effects of EMF means that it can be used for therapeutic benefits, as with the more energetic, ionising X radiations. EMF is now used to treat some bone fractures and diseases. (p. 120). And as ELF effects on human and rat cells (maturation and differentiation) have been demonstrated, this could possibly lead to a “simple and safe biotechnological tool to improve cardiac regenerative potential” (Ledda et al p145)

(The therapeutic use of EMF has a long history, from first century AD , when electric fish were used to cure headaches and gout , to Paracelsus, who studied the medical use of lodestone ,and to Sir Kenelm Digby who described the magnetic cure of wounds. p 120).

The biological effects of static electric and 50 Hz electric and magnetic fields at occupational exposure levels have been investigated at the Bioelectromagnetic Laboratory of the Biophysics dept in the medical faculty of Gazi University, Ankara, Turkey for over 25 years. Under a large range of exposures (0.3 -1.9 kV/m static fields; 1.35-12 kV/m ELF electric field, and 1-3 microtesla ,ELF magnetic fields) the ELF was found to change cellular enzyme activity and free radical formation, suggesting that ELF can be a cancer promoter or co-promoter. (p 157).

This evidence played a role in an IARC evaluation of ELF from power lines which concluded that it was a 2B, possible carcinogen, in 2002.

#### 4. Replicability and Consistency of research results.

“Consistency” of research results is a third , often used, “criterion” or “feature” of evidence, from Bradford Hill. However, like all of his 9 features of evidence (**Table 1**)

Bradford Hill pointed this out in 1965 but his advice has largely been forgotten, even though this asymmetry is stronger now, given our increased knowledge of biological complexity.

The *epidemiological* evidence on mobile phones and head cancers which is now available is reasonably consistent-see below.

However, the absence of consistency and replicability of many *experimental* results is more prevalent: there are many examples of positive and negative studies with a common failure to replicate some of these studies.

It appears that **biological complexity** is likely to be a major reason for this inconsistency, as the number of parameters that are relevant to study outcomes, and which have to be reproduced exactly if studies are to have any chance of replicability and consistency, is very large.

*“Most reviews of the experimental studies do not include analysis of various biological variables and physical parameters when comparing the data on non thermal microwave effects (NTMW) from different studies. As a result, a misleading conclusion is often made that MW at NT levels produce no reproducible effects”.* (Belyaev, I. p 208) .

These parameters include carrier frequency and modulation; polarisation; intermittence and coherence time of exposure; static magnetic field; electromagnetic stray fields; genotype; gender; age; physiological and individual traits, including immune status and oxidative stress; cell density during exposure; duration and timing of exposure; power density; and specific absorption rate.

Blackman (US EPA) has concluded elsewhere that.....*insert*

**Bi-directional effects of MW** need also to be taken into account in replication studies. For example, different exposures to microwaves can either increase or decrease growth rate of yeast cells; radiation damages in mice; respiratory burst of neutrophils in mice; and condensation of nucleoids in E.coli cells and human lymphocytes.

Similarly, when ELF was administered *before* well known genotoxic agents the number of malformed eggs in avians was reduced while the opposite happened when ELF was administered *after* the genotoxic agent. (p 249)

In addition, most studies of MW effects have not used exposure metrics that mimic real exposures; and the widespread exposure of most populations to EMF radiations means that “*it is almost impossible to select unexposed control groups*”.

This absence on unpolluted controls will, in general, dilute any biological effects observed in epidemiological studies such that it is reasonable to conclude that “*studies may be inconclusive, if results are negative, or may underestimate the hazard, if positive*”. Belyaev, I., p 210).

It follows that most “negative” studies are actually “non-positive” because the biological and exposure complexities are such that it is very hard to establish robust negative effects with much confidence.

This another example of the *asymmetry* in the evidence that arises from biological complexity.

The first large scale rodent experiment from prenatal life to death using powerline radiation of 50 MHz in combination with a low dose of gamma radiation has produced positive preliminary results for malignant mammary tumours in female rats. (Soffritti M. et al p 232). 30 years ago the first epidemiological evidence of breast cancer in male telephone company workers was published (Matanoski G.M. et al Lancet 1981,337-737), but studies since have been inconclusive.

Weak combined magnetic fields reduced a key cause of Alzheimer’s disease viz Amyloid-B in mice, indicating its possible therapeutic role in early neuronal degeneration. (Bobkova, N.V. et al, p 235)

Even small differences in magnetic flux density changed the developmental rate of tadpoles when exposed to weak 50 Hz magnetic fields. (Severini M, Bosco, L, p 247).

Cognitive functions including effects on memory have been demonstrated in rodents and “*considering that memory functions are similar in mice and humans with respect to the hippocampus, we may assume that upon*



*using the mobile phone in contact with the head a person may experience cognitive deficits”. (Fragapulo F. , Margaritis, L. p 269).*

The overall evidence on reproductive effects is mixed. *“Overall the results obtained to date through the **epidemiological** approach do not raise strong concern for human reproductive health from the usual occupational and environmental EMF exposure levels”. (Talamanca et al ,p 387).*

However, studies of **male infertility** amongst military personnel and amongst attendees at male infertility clinics, from Norway, Hungary, Poland and the USA, show a consistent pattern of possible damage, which, when combined with the animal evidence, *“raises serious concern,”* and indicates the need for further research. (p 389).

Studies of **pregnant women** provide evidence that is “either absent or weak”. (p394), although one study, which is the only one with measured exposures, showed increased miscarriage rates when there was a total or maximum exposure above 16 mG.

A more pronounced effect was observed when the exposure was in the first 9 weeks of gestation. (p 394). Based on analogous evidence from other reproductive stressors (eg X rays; DES), this is likely to be the most sensitive period for these effects.

**Experimental evidence** on reproductive effects shows *“possible damage to the male reproductive system at doses similar to those encountered in our environments”*. (p 399).

Animal studies on females also show possible damage, such as increases in mortality, reduced litter size, and low birth weight.

Inconsistent results and the absence of an accepted mechanism of action makes interpretation of the evidence difficult. Given that current exposures to the public is a “massive experiment” it is of concern that studies on possible lifetime effects of EMF exposures to the foetus and new born are not rare.

## **5. Children: more sensitive to EMF than adults and need greater protection.**

Children are, in general, more sensitive to exposures to the RF from mobile phones than adults, as pointed out by the UK National Radiological Protection Board in 2002 (Stewart report), and again in 2004. As the existing public safety limits are based on an adult male head

this is a cause for concern, especially as about half of the RF radiation from the phone is absorbed by the head, (p 303).

Children's skulls are thinner, and their brains are less dense and more fluid, than adult brains. Children's brains also have higher electrical permittivity and conductivity which means that they can absorb 50-100% more RF energy than the adult head ( Table 2 ,p 310/1, Han, Y. Y., Gandhi, O.P., DeSalles, A., Herberman R.B., Davies, D.L., p 301-318).

Recent studies by Wiart (2008) for French Telecom, and Kuster (2009), shows that *"a given signal is absorbed about twice as deeply into the bone marrow of the head and cortex of a child in contrast with that of an adult, even though systemic absorption may not differ substantially"*. (p 312)

The recent change in the recommendation from IEEE to average EMF exposures over 10 grams of the head ,compared to 1 gram before , when estimating SAR (Specific Absorption Rate) values, leads to a less stringent protection for both adults and children. (p312).

Other changes in the test guidelines for head absorption allow RF exposures that are 8-16 times higher than previous guidelines. P 312 and table 2, p 313).

In addition to absorbing proportionately more radiation than adults for the same exposure , the brains of children are more sensitive to that radiation because their brains are still in developmental stages compared to adults eg less neural integration and myelination until about the twenty years old. (p312.)

## 6. Cancer Epidemiology

For **ELF** (eg from power lines) the International Agency for Research on Cancer concluded in 2002 that this exposure was a 2b (possible) carcinogen, based on sufficient epidemiology but inadequate animal evidence and unclear mechanisms of action.

The evidence from studies of **workers** exposed to high (eg usually "from 2010 W/m<sup>2</sup>, with peaks of 10-30 W/m<sup>2</sup>, for 1-2 hours per shift, compared to the public continuous exposure to usually an average of below 0.1 W/m<sup>2</sup>"-p 359) **RF** microwave radiation (eg to radar workers, metrologists, mobile phone technicians, and plane flight workers etc) is inconsistent.

However, it provides “*a coherent pattern of data*” on various cancers, particularly those of the blood ((hematopoietic) system. (p 361).

(Exposures of other workers to EMF can be considerable in modern offices and “it is strongly recommended that periodic EMF exposure measurements should be done” particularly to identify hot spots of high exposures. p379),

For **the public exposure to RF from mobile phones**, the evidence on head cancers is now consistent for those exposed for longer than 10 years.

Both the Hardell studies and the Interphone studies indicate potential head tumour risks of between 1.5 -2. 0 times the normal rates for head tumours, (but up to 5 times for the younger groups in the Hardell study), particularly for gliomas and acoustic neuromas which are generally on the same side of the head used when phoning. (Hardell, p 363).

Tumours in the region of the temporal lobe are most common. This is the part of the brain that, in general, receives most radiation from the phone. A recent review of 110 phone models showed that exposure to radiations is generally higher in the temporal lobe, which is a part of the brain that is near to the ear. (Cardis E, Deltour I, Mann S, Phys. Med Biol.53, 2771-83, 2008)

Since publication of the Ramazzini monograph the lead author for the Interphone study, Cardis E., and another Interphone author, have published a review of both the Hardell and Interphone results.

They have concluded that “*The overall balance of the above-mentioned arguments (about biases and effects) however, suggests the existence of a possible association*”. These results “*are of concern*” as even a small risk at the individual level will represent a considerable public health issue. The adoption of such simple and low cost exposure reduction methods such as texting, hand free kits and/or the loudspeaker mode “*could substantially reduce exposure*”. ..*the adoption of such precautions, particularly among young people, is advisable*”.

(Cardis E. , Sadetzki S, “Indications of possible brain tumour risk in mobile phone studies: should we be concerned?”, Occupational and Environmental Medicine, March 2011, vol 68, n 3.

## **7. Implications of biology for current safety guidelines and test methods.**

Current guidelines from IEEE and ICNIRP are only based on short term EMF exposures that are high enough to cause thermal effects. These are inadequate to provide protection to the public against long term effects from lower levels of exposure. Neither do they account for the pulse-like exposures modulated at low frequencies that are common from the modern 2G and 3 G appliances. (p314).

The biological evidence concerning the non thermal effects of EMF (indications of head cancer, permeability of the brain/blood barrier (p 319,333) ; expression of shock proteins; genotoxic damage, neurological, and possibly reproductive effects), though still limited and controversial, is sufficient, on a sensible precautionary basis, to justify biologically based and lower safety limits for the public.

Such evidence also justifies more realistic test methods for RF absorption from RF.

Recommendations for such lower limits have been proposed by the BioInitiative group; the Selatun Scientific Panel (Reviews on Environmental Health V 25 n 4 2010); and others. These have been adopted in some cities and regions of Europe.

Whilst the state of the science does not predict obvious choices of particular lower limits it does allow the choice of pragmatically based and more biologically relevant limits which would provide better protection of health.

(Funding bias –use Slesin slides)